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V. G. KHLOPIN'S WORK IN THE FIELD OF GEOCHEMISTRY

[A digest]

The work of V. G. Khlopin in the field of geochemistry began with investigations on the subject of natural springs containing boron compounds and the occurrence of boron in nature. He established that enrichment with boron takes place in the waters of petroleum-bearing regions and that the occurrence of boron is typical for such regions. Khlopin's work on the geochemistry of boron proved to be of practical importance in locating rich natural occurrences of borates.

Later on, beginning in 1922, Khlopin and his collaborators concentrated on the geochemistry of radioactive elements and noble gases. During the period from 1922 to 1936, a great number of samples of natural gas was analyzed for helium and argon content. The results of this work permitted the compilation of a map showing the distribution of these gases throughout the USSR. Khlopin discovered a new type of natural gas well, the so-called air well. On the basis of the lowered proportion of Ar/N in certain gas samples in comparison with air, Khlopin concluded that a part of the nitrogen in the earth crust is of biological origin. Furthermore, he came to the conclusion that there is a continuous gas exchange between the subterranean and outer atmospheres, and that natural waters participate in this exchange as far as noble gases are concerned. As a result of this exchange, subterranean gas atmospheres may be considerably enriched in the heavier noble gases and impoverished in regard to their neon content in comparison with air.

As far as the geochemistry of helium is concerned, diffusion of helium out of minerals is of importance. The energy of activation which must be imparted to helium in order that the force with which it is bound in lattices of minerals be overcome varies with different minerals. This energy could be determined experimentally and was found to vary from several thousand small calories to many tens of thousands of small calories [per gram mol?]. The separation of helium from solid substances proceeds in two stages, according to the experimental results: first there is desorption from the internal surface of the solid, and second, diffusion through the crystal lattice.

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Khlopin proposed determination of radioactive equilibrium as a method of studying the migration of radioactive elements of the uranium series. This method has been very successful in the investigation of secondary deposits. An increased concentration of radium in natural waters which are associated with petroleum occurrences could be established by Khlopin. This increased concentration is connected with a definite chemical composition of the water.

In the general survey of noble gas occurrences, analytical appliances constructed by Khlopin proved to be of advantage. One of them determines the sum of helium and neon in mixtures. Another determines neon separately. A third is constructed in such a manner that the sum of heavy and light noble gases can be determined.

Khlopin has devised many methods for the analysis of radioactive elements. Among them, a procedure for the determination of quadrivalent uranium is of particular interest, because the ratio U^{IV}/U^{VI} permits conclusions in regard to oxidative processes in nature. Khlopin proposed a volumetric method for determination of the cations U, V, and Fe occurring simultaneously in a mixture. He has also devised volumetric procedures for determination of V and U [occurring separately]. In connection with investigations on the geochemistry of boron, he developed a volumetric method for the determination of small quantities of boron.

Khlopin has published an excellent manual for the analysis of mineral waters.

In the field of radiogeology, Khlopin was concerned with the determination of geological age and the heat regime of the earth. In the first of these two subdivisions, he pointed out the possibility of establishing the absolute age of very young geological formations by determining the ratios Ra/U and Io/U . He applied the helium method in determining the age of North Karelian pegmatites and obtained values which were too low, because the helium had, to a considerable extent, evaporated from the mineral. By applying the lead method, values which checked perfectly could be obtained. On the basis of these values, Northern Karelia was found to be the oldest spot on the earth crust. Using the same samples, Khlopin found that the age could also be determined by using the oxidation method and basing this method on the scheme $2 UO_2 \rightarrow PbO + UO_3 (+8He)$. The values obtained by this method checked with results of the lead method on samples which had not deteriorated.

Quite recently, Khlopin proposed a method for determination of the age of geological occurrences on the basis of the ratio of xenon to uranium. This method is based on the assumption that the spontaneous fission of uranium proceeds in an analogous manner to the fission of uranium under the action of slow neutrons. In order to carry out an experimental check, Khlopin devised a special apparatus for determining xenon in uraninite. The geological age of the mineral was found to be 1.68×10^9 years, which agrees with the figure found by the lead method, 1.85×10^9 years. Millions of cubic meters of xenon have been formed by the fission of uranium and in some special cases the fact that the xenon may be formed by uranium has to be considered.

In determining the age of minerals by the helium method, possible losses of helium must be considered. On the basis of extensive experimental material collected by Khlopin, it can be concluded that these losses are negligible when the mineral has a dense crystal lattice and has not deteriorated. Many minerals contain captured helium of cosmic origin, Beryl and boron and lithium minerals contain an excess of helium. By determining the isotopic composition of helium contained in beryl or spodumene, Khlopin found that this helium could not have formed as a result of nuclear fission, because it has the same content of He^3 as that which is found in helium of natural gas wells. In other words, helium must have been selectively occluded by the minerals in the course of their formation.

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Khlopin has carried out a rather important investigation on the effect of fission in the actinium series on the heat balance of the earth.

Khlopin collaborated with V. I. Vernadskiy in the founding and organization of the USSR Radium Institute.

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